

## Wavelength Router, also referred to as Wavelength Routing Element™ or WRE

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## The Opportunity

- DWDM optical transport networks require wavelength-selective switching functions to provide network management for wavelength-based service provisioning, bandwidth management, optical-layer protection and restoration.
  - OADM, WSXC and protection switches
- No integrated all-optical solutions exist yet
- We can be the first to offer integrated all-optical dynamic wavelength routing

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## Everybody Else's Solution

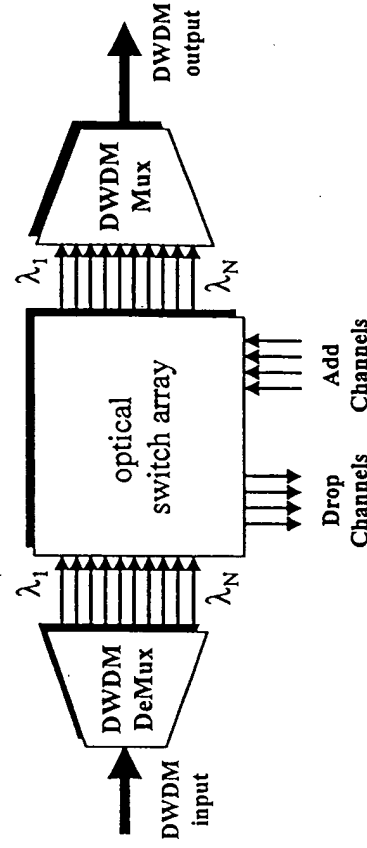
1. De-multiplex the DWDM stream into individual wavelengths on separate fibers
2. Switch the optical fibers electronically or optically (OXC, FXC)
3. Re-multiplex all the fibers into DWDM.

Complex and Expensive!

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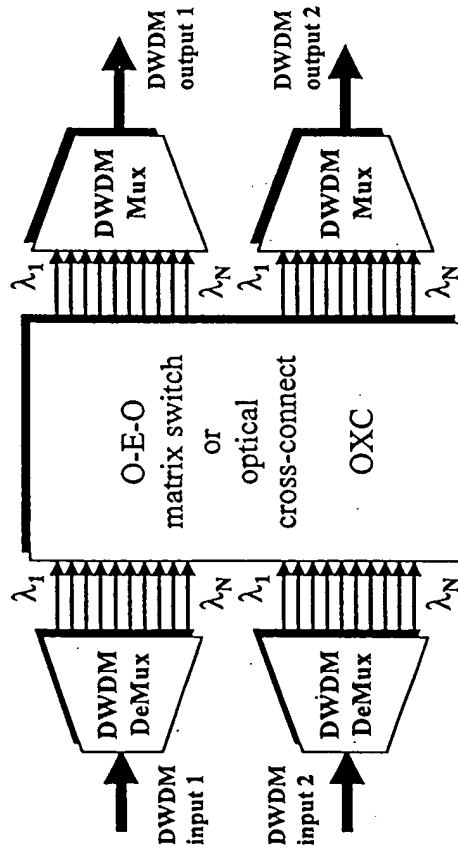
## OADM Conventional Solution



Cost = \$3,000 per  $\lambda$

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## WSXC Conventional Solution



Cost = \$3,000-\$5,000 per  $\lambda$  per fiber

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## An Alternative Approach

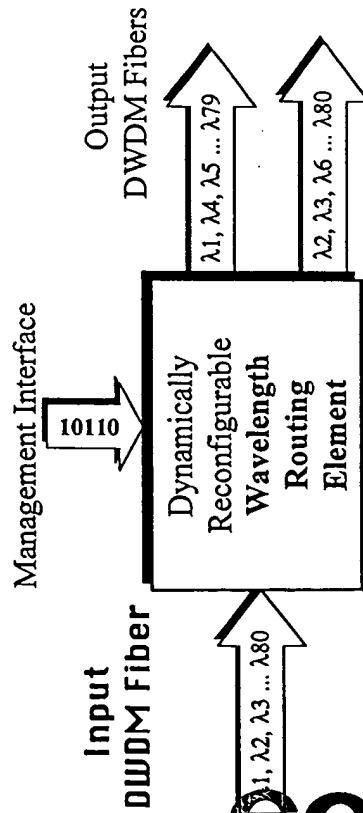
- Network Photonics has a novel solution:

### Wavelength Routing Element™

*All-optical wavelength routing component which enables networking functions by directly switching wavelengths instead of switching fibers.*

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## Wavelength Routing Element™

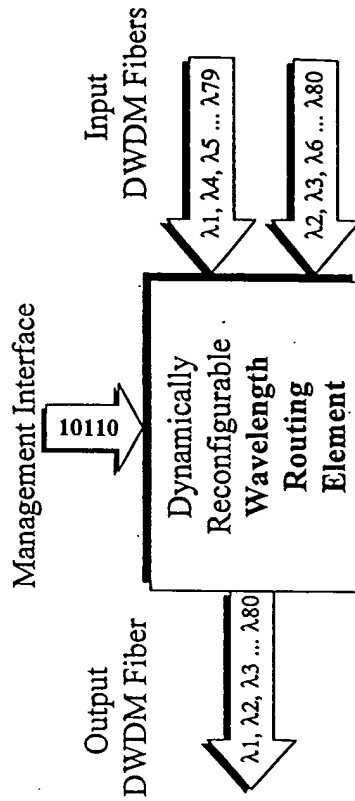


*Any wavelength to any output*

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## Wavelength Routing Element™

it works in both directions



*Any wavelength from any input*

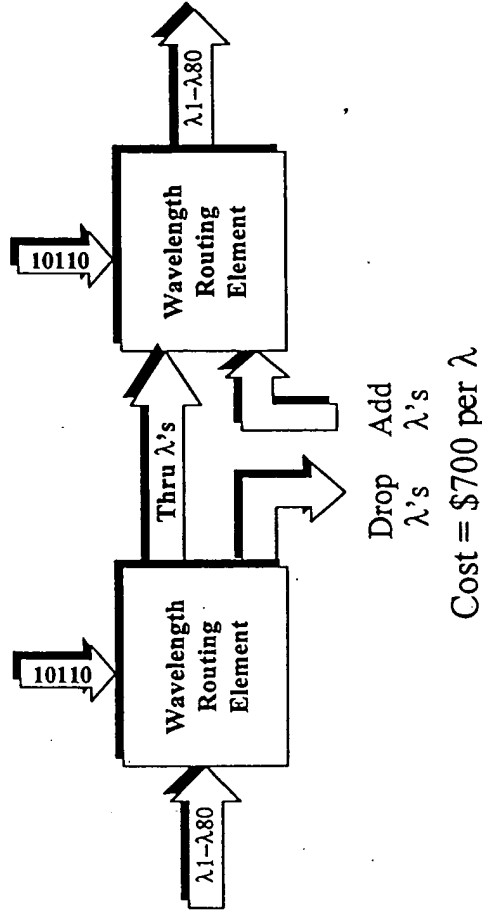
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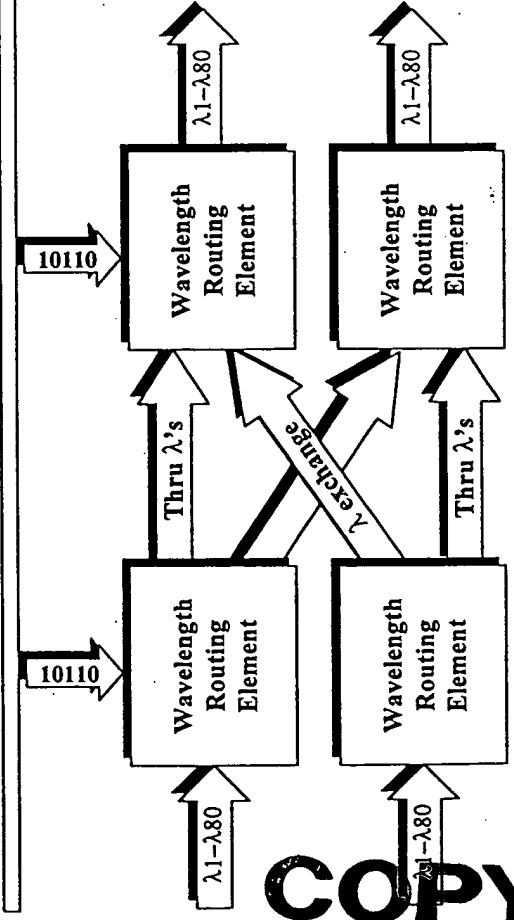
## A Building Block

- The WRE is a building block for many optical layer applications:
  - Optical Add-Drop Multiplexer
  - Wavelength-Selective Cross-connect
  - Wavelength-Selective Protection Switching
  - Wavelength Distribution Router

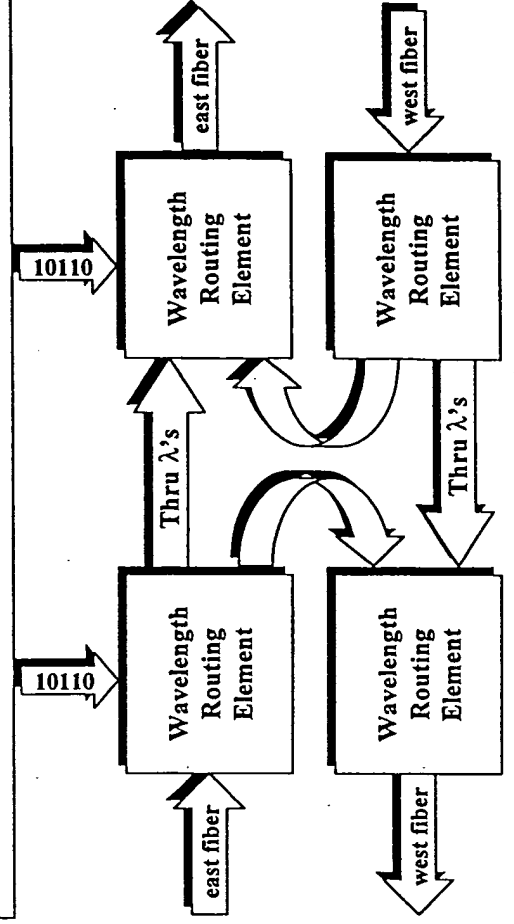
## WRE Configurations: Optical Add/Drop Multiplexer (OADM)



## WRE Configurations: Wavelength-Selective Cross-Connect



## WRE Configurations: BLSR Protection Switching



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## WRE Technology Overview

- 2 parts working in combination:
  - Dispersion-Free Spectrometer (DFS)
  - Micro-optic Routing Array (MRA)
- DFS performs spatial conversion of multiplexed wavelengths
- MRA performs switching/routing functions

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## MRA Overview

- Implemented as an array of micro-optic retroreflectors
- Performs either dynamic or static routing
  - dynamic design uses electronic actuation
  - static design requires no power
- Non-blocking and latching

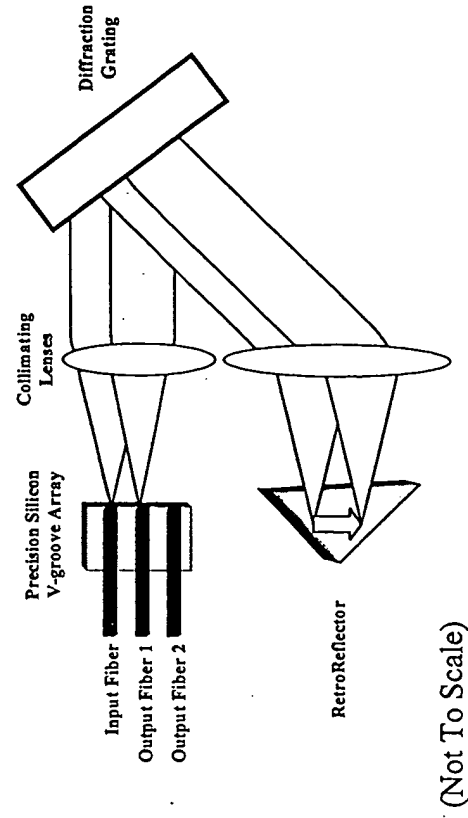
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## DFS Overview

- DFS is the heart of the WRE
  - a single design for dynamic and passive WREs
- Requires only one optical element both for wavelength separation and recombination
- Based on free-space diffractive optics
  - unique light path eliminates chromatic dispersion
- no electronics or moving parts

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## DFS Light Path



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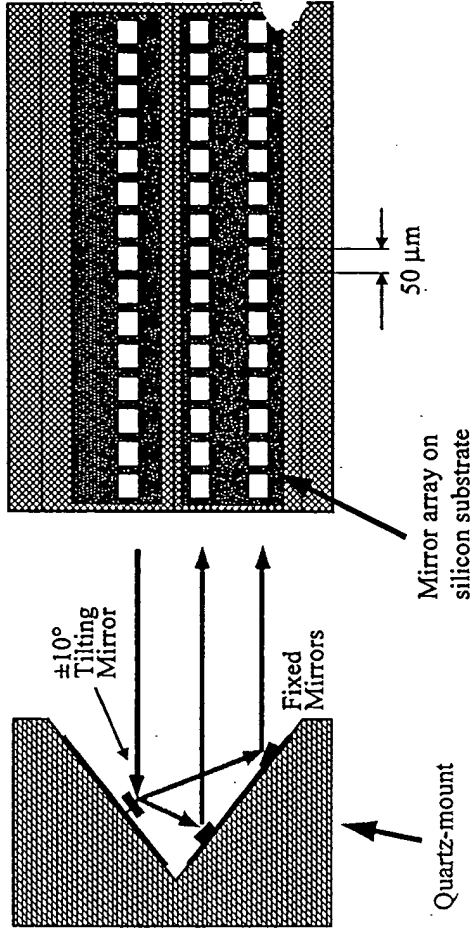
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## Dynamic MRA Implementation

- MEMS tilting micromirror array
  - proprietary design
  - one switching mirror per  $\lambda$  fabricated on a 5 mm x 50 mm silicon substrate
  - requires only  $\pm 10^\circ$  mirror tilt
    - ◆ can use Texas Instruments DMD technology
    - ◆ CMOS semiconductor fab process

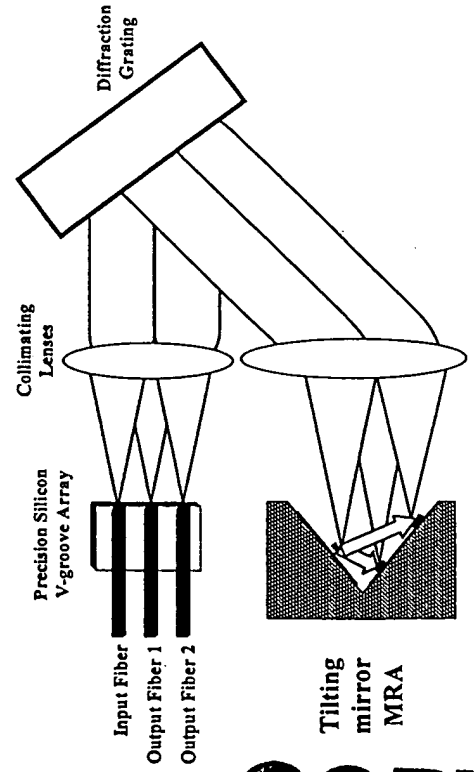
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## MEMS Tilting MicroMirror Design



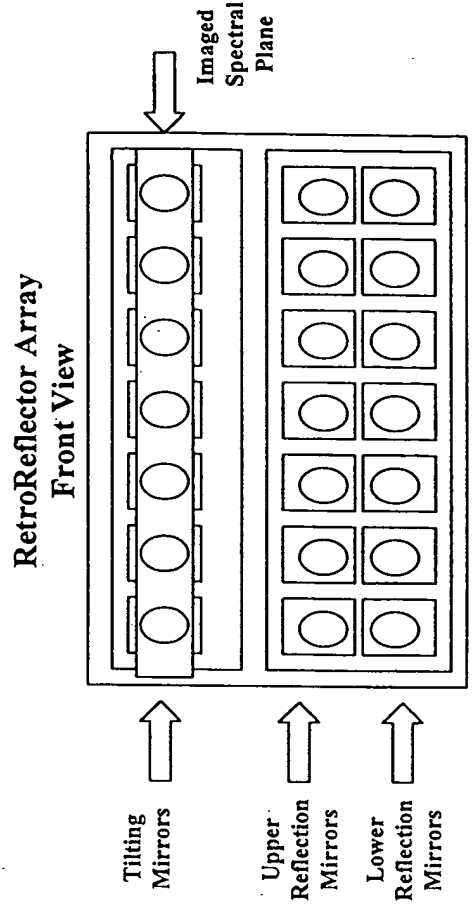
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## WRE Switching



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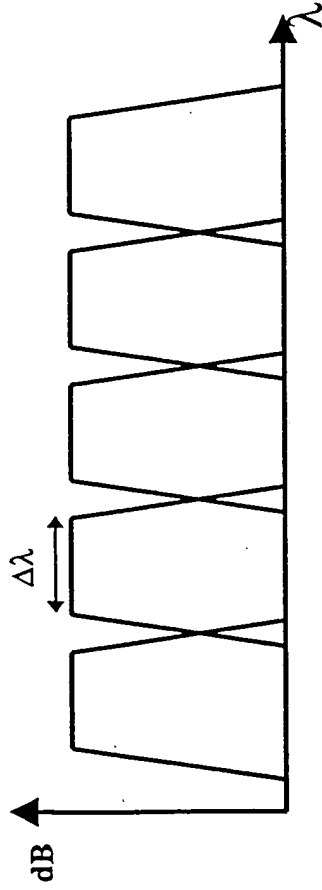
## Directly Switching Wavelengths



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## Trapezoidal Passbands Superior Optical Performance



- 50 GHz channel spacing
- uniform gain characteristic across all channels
- low insertion loss - 3dB
- low crosstalk and high SNR - 40dB

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## Dynamic WRE

- Dynamically-reconfigurable routing
- 250  $\mu$ sec switching time
- Latching
  - retains configuration with power off
- Scales to higher or lower DWDM channel densities

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## Passive WRE

- Static MRA is fabricated on a silicon chip using gray-scale photolithography
  - no electronics or moving parts
  - proprietary design for 3-D retroreflector array
  - low-cost volume-fabrication process
  - same DFS as DWRE

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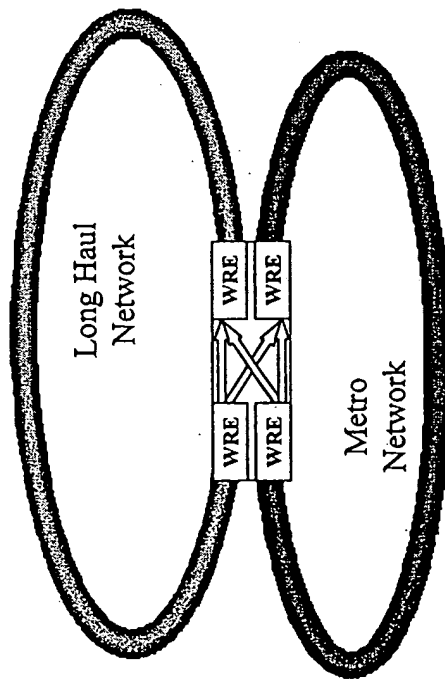
## WRE Value Proposition

- Integrated subsystem functionality
  - simpler system design
  - ♦ no need to de-mux & re-mux
  - ♦ far fewer switching elements
  - ♦ far fewer fiber connections
- Lower system cost
  - less than \_ the cost of alternatives
- Superior optical performance
- Higher system reliability

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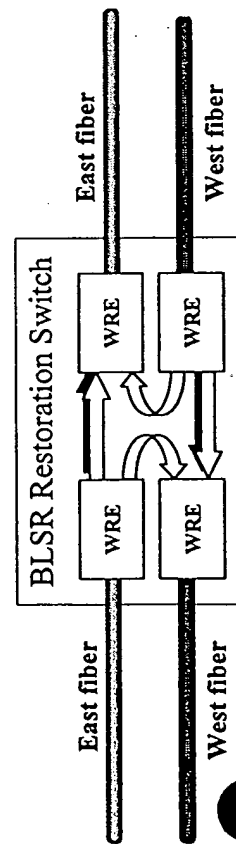
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## Network Applications: Network Interconnect



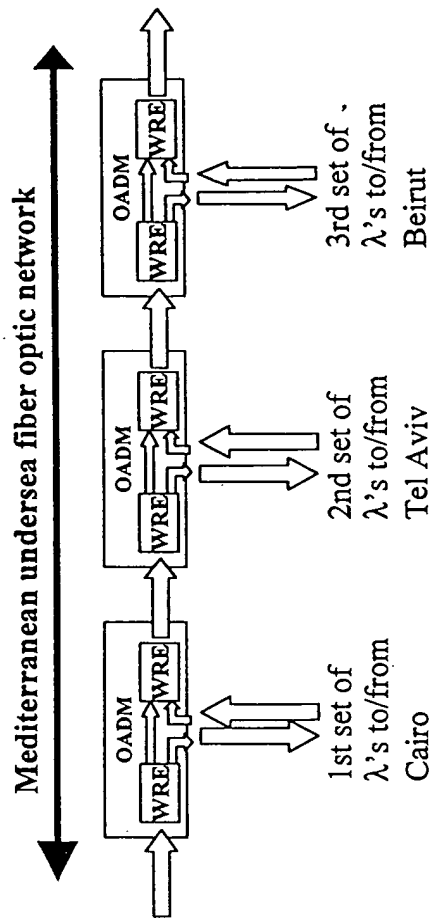
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## Network Applications: 2-f BLSR Restoration



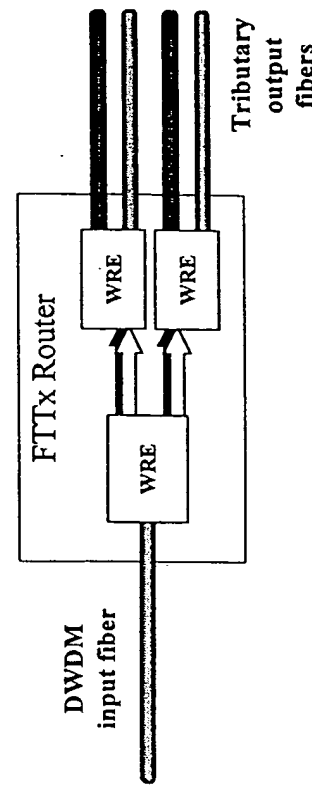
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## Network Applications: Undersea Passive OADM



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## Network Applications: FTTx Distribution Router



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